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No place like home: A national study on firearm-related injuries in the American household

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ABSTRACT

Background: We aimed to examine the prevalence of, and describe factors associated with, firearm-related injuries in American households.

Methods: Using the 2010–2016 ACS-TQIP database, all ICD-9/10 external causes of injury for firearm-related injuries were queried with the place of occurrence designated as "home". Causes of injury were identified as assault, intentional self-injury, and unintentional injury. Univariate then multivariable regression analyses were performed to identify factors associated with each injury type.

Results: 12,657 firearm-related injuries in households were identified. Of those, 49.9% were victims of assault, 35.7% were intentional self-injury, and 14.4% were unintentional. Mortality was highest among self-inflicted injuries (52.4%), followed by assault (12.9%), and unintentional injuries (5.9%). On multivariable analysis, age <45 years, African-American race, and drug use were independently associated with an injury secondary to assault. Age >65 years, White race, psychiatric illness, and alcohol use disorder were independently associated with intentional self-injury. White and American-Indian race were independently associated with unintentional injuries.

Conclusions: Assault is the most common cause of home-related firearm injury requiring hospitalization, while intentional self-injury is the most lethal.

Introduction

Firearm-related injury is a major public health concern in the United States (US). Compared to other high-income economy countries, Americans endure a disproportionate burden of firearm violence.[1] At 40,000 fatalities each year, deaths from firearms exceed those from falls and motor vehicle accidents.[2] Moreover, between 2001 and 2013, the rate of non-fatal injuries has increased from 22.1 to 26.7 per 100,000 population.[3] These injuries burden the healthcare system, whereby initial hospitalization costs for patients injured by firearms in the US are approximated at 730 million dollars per year, a number multiplied times over when extended care and loss of employment are accounted for.[4] Gun ownership is embedded within American culture, with the US being one of three countries that affords constitutional protection for gun ownership.[5] Ease of access to firearms, made available through gun ownership, has been associated with household violence, suicide, and unintentional injury.[6–8]

To understand the nature and extent of household gun-related injuries, we evaluated the American College of Surgeons - Trauma Quality and Improvement Program (ACS-TQIP) database, one of the largest and most comprehensive national trauma databases. The aim of our study was to investigate the prevalence of firearm-related injuries requiring admission to ACS-TQIP verified trauma centers, and the independent factors associated with gun-related injuries in the American household.

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Materials and methods

Study design

The ACS-TQIP database years 2010–2016 were queried. The database is comprised of 1.4 million trauma admissions from more than 825 trauma centers across the United States. It contains over 100 data items, which include patient demographics, comorbidities, type and mechanism of injury, Injury Severity Score (ISS), Abbreviated Injury Scale (AIS), prehospital and emergency department (ED) vital signs, diagnoses, in-hospital procedures, complications, and mortality as well as discharge disposition. ACS-TQIP provides standard data collection and risk-adjusted outcomes, allowing participant centers to improve patient care. There are several inclusion/exclusion criteria at the center-level and patient-level that determine what patients are eligible to be included in the database. A relevant center-level criteria mandates that the participating center must be a Level I or II ACS verified or state designated trauma center, and the most relevant patient-level criteria is that, for a patient to be included, they must have suffered at least one AIS injury with severity of greater than or equal to 3 in one of eight body regions.

This study was ruled exempt by the Institutional Review Board (IRB) as the ACS-TQIP database contains only de-identified data.

Patient selection

All trauma patients aged ≥16 years, who had an International Statistical Classification of Diseases (ICD)-9 and 10 external cause of injury (ECODES) indicating firearm-related injury and place of occurrence designated as 'Home' were included in the study. A firearm-related injury is defined as a penetrating injury from a weapon that uses powder charge to fire a pellet projectile.[9] The definition used includes handguns, rifles, and shotguns, but excludes gas-pressurized weapon such as air guns, ball bearing (BB) guns, and paintball guns. The incidences were categorized by the intention of firearm use as defined by ICD9/10 ECODES in the ACS-TQIP database: assault, intentional self-injury, and unintentional injury. Entries with an indeterminate intention behind the injury were excluded.

Variables and outcomes analyzed

The following data were retrieved from the ACS-TQIP database: demographics (age, gender, race, ethnicity), comorbidities (including a history of psychiatric illness, alcohol abuse, or drug abuse), ED information (vital signs, Glasgow coma score (GCS), injuries sustained based on the Abbreviated Injury Score (AIS), injury severity based on the Injury Severity Score (ISS), hospital and intensive care unit (ICU) length of stay), discharge destination, and mortality. The primary outcome was to describe the patterns of gun victimization at home, as categorized by the intention of firearm use. Our secondary outcome was to determine factors associated with each cause of firearm-related injury.

Statistical analysis

Categorical variables were presented as totals and percentages. Continuous variables were reported as medians with interquartile range [IQR]. The Chi-square test was used for comparison of discrete variables, and the Wilcoxon rank sum test as used for the analysis of continuous variables. Odds ratios for being a victim from each cause of firearm-related injury were calculated using a multivariable logistic regression adjusted for variables that have p-values <0.2 on univariate analysis. A value of $p \leq 0.05$ was deemed statistically significant. All analyses were performed using STATA 14.2 (Stata Corp, College Station, TX).

Results

During the 7-year study period, a total of 47,241 firearm injuries were identified in the database, of which 27,615 cases had an identifiable scene of injury. From those, 12,657 occurred at home. Overall, the victim population was predominantly male (82.6%), White individuals (56.5%), with a median age of 33 years. Injury causes were divided across intent as follows: assault (49.9%), intentional self-injury (35.7%), and unintentional injuries (14.4%). Fatality rates were 12.9%, 52.5%, and 5.9% across assault, intentional self-injury, and unintentional injury victims, respectively **[**Fig. 1**]**.

Victims of assault

Among the 6310 victims of assault, 372 cases (5.9%) were sustained during a legal intervention. Most victims of assault were young (median age: 29 years) males (84.9%), of African American (51.8%) or white (33.4%) race. A history of drug disorder was more common in the victims of firearm assault (16.3%) as compared to patients with intentional self-injury (7.8%) or unintentional injury (9.8%) ($p < 0.001$) **[**Table 1**]**. Chest (40.9%) and abdominal (42.9%) injuries were more common among assault victims than in the other two groups ($p < 0.001$). The extremities were most prevalent injured body region among the assault group (61%), with severe injury (ISS>16) sustained in 45% of patients **[**Table 2**]**. Operative intervention was required in 39% of patients, 8% of patients expired in the ED, and 12.9% did not survive hospital stay. Among survivors, median hospital stay was 7 days, with 80.7% of patients being discharged home **[**Table 3**]**.

Victims of intentional self-injury

In this cohort, 4513 patients (35.7%) attempted or completed suicide. Patients in this group tended to be older than victims of assault and unintentional injury at a median age of 43 years. Males (79.3%) of White race (82.2%) comprised most cases in this group. A history of psychiatric illness (23.4%) and alcohol use disorder (12.1%) were reported more frequently in patients presenting with self-harm ($p < 0.001$) **[**Table 1**]**. In the ED, patients in this group were more likely to be hypotensive (19.5%) and comatose (64.5%) as compared to victims of assault or unintentional injury ($p < 0.001$). Head/Neck (65.3%) and facial (13.3%) injuries were the most commonly injured regions in this group, and found more commonly than in patients suffering assault or unintentional injury ($p < 0.001$). 64.6% of patients presenting after intentional self-harm had severe injury (ISS>16) [Table 2]. In this group, 52.8% of patients went to the ICU, 21.7% required immediate operative intervention, and 15.3% died in the ED. The group mortality rate was 52.5%. Among survivors, median hospital stay was 10 days, the longest between the three groups ($p < 0.001$) with 40.6% of patients being discharged home and 36.5% to rehabilitation **[**Table 3**]**.

Victims of unintentional injury

Unintentional injuries accounted for 1834 patients (14.4%) in our cohort. Young (median age: 33 years) males (82.9%) of White race (72.8%) comprised most cases in this group **[**Table 1**]**. Hypotensive (6.8%) and comatose (9.2%) patients were the least prevalent in this group of patients ($p < 0.001$). Extremity injuries were the most commonly injured body region among the victims (69.8%) and more prevalent than in other groups ($p < 0.001$) **[**Fig. 2**]**. Injury

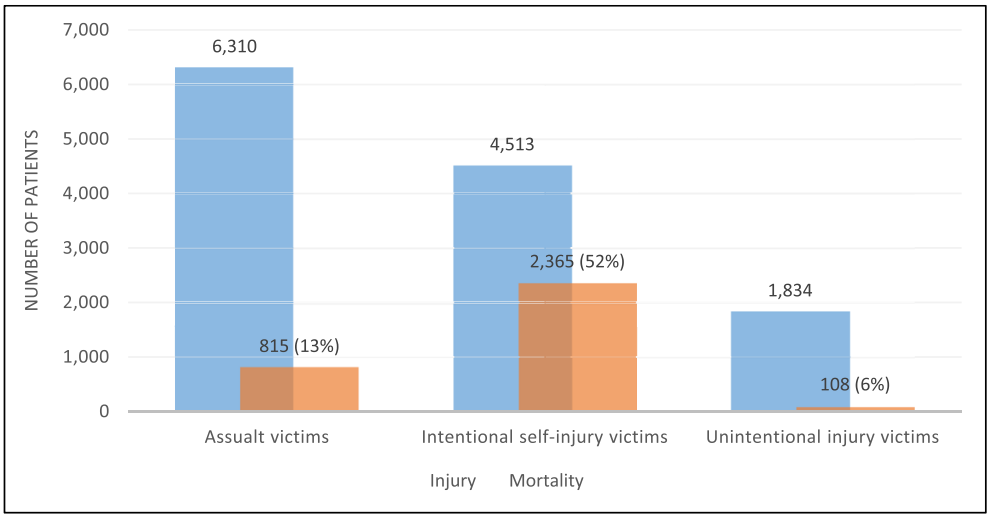

Fig. 1. Numbers of injuries and fatalities (%) due to firearms in households admitted to ACS-TQIP participating hospitals between 2010 and 2016.

Table 1
Demographic data of firearm-related injuries in the household across different intents.

Variables	All patients (n = 12,657)	Assault (n = 6310)	Intentional self-injury (n = 4513)	Unintentional (n = 1834)	pValue
Sex, male	10,445 (82.6%)	5351 (84.9%)	3575 (79.3%)	1519 (82.9%)	<0.001*
Age, median [IQR]	33 [24–49]	29 [23–40]	43 [28–58]	33 [23–51]	<0.001†
Age <45	8702 (68.8%)	5134 (81.4%)	2354 (52.2%)	1214 (66.2%)	<0.001*
Ethnicity, Hispanic	1275 (10.1%)	851 (13.5%)	269 (6.0%)	155 (8.5%)	<0.001*
Race					<0.001*
White	7152 (56.5%)	2107 (33.4%)	3709 (82.2%)	1336 (72.8%)	
African American	3929 (31.0%)	3268 (51.8%)	373 (8.3%)	288 (15.7%)	
Asian	93 (0.7%)	39 (0.6%)	36 (0.8%)	18 (1.0%)	
American Indian	83 (0.7%)	32 (0.5%)	27 (0.6%)	24 (1.3%)	
Other	1400 (11.1%)	864 (13.7%)	368 (8.2%)	168 (9.2%)	
Alcohol Use Disorder	1133 (9.0%)	448 (7.1%)	545 (12.1%)	140 (7.6%)	<0.001*
Psychiatric Illness	1575 (12.4%)	365 (5.8%)	1058 (23.4%)	152 (8.3%)	<0.001*
Drug Use Disorder	1564 (12.4%)	1030 (16.3%)	354 (7.8%)	180 (9.8%)	<0.001*

-Psychiatric Illness: documentation of the presence of pre-injury depressive disorder, bipolar disorder, schizophrenia, borderline or antisocial personality disorder, and/or adjustment disorder/post-traumatic disorder (must present prior to injury).
-Drug use disorder: present prior to injury, excluding tobacco use and alcohol use disorder.
*P-value of a chi-squared test.
†P-value of a Kruskal-Wallis test.

Table 2
Emergency department and injury data of firearm-related injuries across different intents.

Variables	All patients (n = 12,657)	Assault (n = 6310)	Intentional self-injury (n = 4513)	Unintentional injury (n = 1834)	p-value
SBP, median [IQR]	128 [108–145]	130 [110–146]	122 [99–143]	132 [116–148]	<0.001†
Hypotension (SBP <90 mmHg)	1630 (13.6%)	686 (11.5%)	821 (19.5%)	123 (6.8%)	<0.001*
Pulse, median [IQR]	94 [79–111]	94 [80–110]	96 [78–116]	90 [77–104]	<0.001†
Pulse >100	4815 (39.6%)	2371 (39.1%)	1893 (44.2%)	551 (30.5%)	<0.001*
GCS, median [IQR]	15[3–15]	15[14–15]	3[3–15]	15[15–15]	<0.001†
Comatose (GCS <8)	4121 (33.2%)	1113 (18.0%)	2843 (64.5%)	165 (9.2%)	<0.001*
Signs of life on admission	11519 (97.6%)	5672 (98.1%)	4103 (96.2%)	1744 (99.5%)	<0.001*
ISS, median [IQR]	16[9–25]	14[9–22]	25[13–26]	9[9–13]	<0.001†
ISS >16	5563 (45.3%)	2450 (40.0%)	2800 (64.6%)	313 (17.2%)	<0.001*

SBP: Systolic blood pressure; GCS: Glasgow Coma Scale; ISS: Injury Severity Score.
*P-value of a chi-squared test.
†P-value of a Kruskal-Wallis test.

severity was also notably lower (median ISS: 9) in victims of unintentional injuries as compared to other groups ($p < 0.001$) **[**Table 2**]**. In this group, 44.1% of patients went to the OR, 37.7% went to the floor, and 1.4% died in the ED. The group mortality rate was 5.9%. Among survivors, median hospital stay was 5 days, the shortest between the three groups ($p < 0.001$) with 85.3% of patients being discharged home **[**Table 3**]**.

Predictors of being a victim of assault, intentional self-harm, or unintentional injury

On multivariable logistic regression, several factors were identified that independently increase an individual's odds of sustaining firearm injury in the household across different intents. Independent factors associated with being a victim of assault

Table 3
Outcomes of firearm-related injuries across different intents.

	All patients (n = 12,657)	Assault (n = 6310)	Intentional self-injury (n = 4513)	Unintentional injury (n = 1834)	p-value
ED disposition					<0.001*
Expired	983 (7.8%)	269 (4.3%)	689 (15.3%)	25 (1.4%)	
Floor	2557 (20.2%)	1482 (23.5%)	383 (8.5%)	692 (37.7%)	
ICU	4029 (31.8%)	1358 (21.5%)	2382 (52.8%)	289 (15.8%)	
OR	4910 (38.8%)	3121 (49.5%)	980 (21.7%)	809 (44.1%)	
Home	4 (<1%)	4 (0.1%)	0 (0.0%)	0 (0.0%)	
Other	174 (1.4%)	76 (1.2%)	79 (1.8%)	19 (1.0%)	
Hospital Mortality	3288 (26.0%)	815 (12.9%)	2365 (52.4%)	108 (5.9%)	<0.001*
Characteristics of hospital survivors					
Number (%)	9369 (74.0%)	5495 (87.1%)	2148 (47.6%)	1726 (94.1%)	<0.001*
Hospital LOS, median [IQR]	7[4–13]	7[4–13]	10[5–19]	5[3–8]	<0.001†
ICU LOS, median [IQR]	4[2–8]	4[2–7]	5[3–10]	3[2–6]	<0.001†
Discharge Disposition					<0.001*
Home	6776 (72.3%)	4432 (80.7%)	872 (40.6%)	1472 (85.3%)	
Rehab	1799 (19.2%)	803 (14.6%)	784 (36.5%)	212 (12.3%)	
Other	794 (8.5%)	260 (4.7%)	492 (22.9%)	42 (2.4%)	

ED: Emergency Department; ICU: Intensive Care Unit; OR: Operating Room; LOS: Length of Stay.
*P-value of a chi-squared test.
†P-value of a Kruskal-Wallis test.

included age <45 years (OR: 2.0, 95% CI: 1.9–2.2), African American race (OR: 9.3, 95% CI: 8.3–10.3), Hispanic ethnicity (OR: 3.7, 95% CI: 3.2–4.2), and a history of drug abuse disorder (OR: 2.2, 95% CI: 1.9–2.5). Independent predictors of being a victim of intentional self-harm included age>65 years (OR: 3.0, 95% CI: 2.9–3.5), White race (OR: 4.9, 95% CI: 4.5–5.6), history of psychiatric illness (OR: 3.8, 95% CI: 3.3–4.3), and alcohol use disorder (OR: 1.5, 95% CI: 1.3–1.7). Independent risk factors of being a victim of unintentional injury included White (OR: 2.5, 95% CI: 2.3–2.9) or American Indian race (OR: 4.5, 95% CI: 2.8–7.3) [Table 4]. Fig. 3 plots adjusted probabilities of assault, intentional self-harm, and unintentional injury across age.

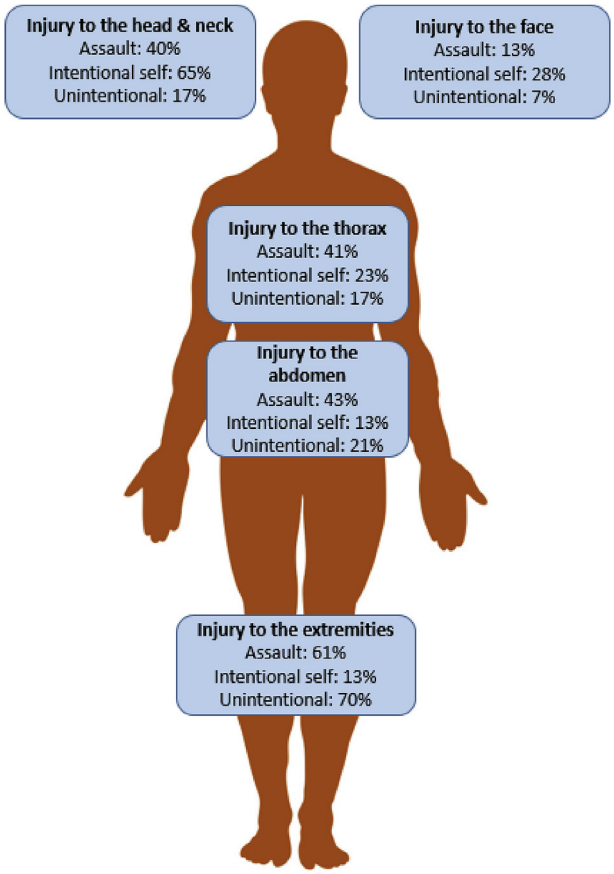

Fig. 2. Prevalence of injuries to body regions based on the intention of fire-arm use.

Discussion

In this analysis, we aimed to quantify the burden of firearm injury reported to ACS-TQIP participating hospitals in the contemporary United States household, where we find that approximately one-fourth of all firearm-related injuries took place at home. The ACS-TQIP allowed us to describe the firearm-related injuries as related to specific body regions and vital signs on presentation to the ED.

This analysis shows that firearm-related injuries at the household were most frequently the result of assault. While ACS-TQIP does not provide information pertaining to the victims of the alleged assault, several previous studies demonstrate that majority of the injured comprise household members or acquaintances.[9–11] Unknown intruders represent an uncommon victim, and gun use for self-defense was reported at only 0.9%.[12] Kellermann et al. suggested that only 3% of victims were unknown to the shooter, while 55% of victims were residents of the household.[13] In addition, similar to findings in this analysis, numerous studies have shown a strong correlation between gun interpersonal violence and substance use.[14,15] Furthermore, the vast majority of victims of assault in our cohort were discharged back to home after hospitalization. This study suggests that trauma centers have a unique opportunity to intervene in regards to discharge planning. Expansion of violence prevention programs, such as the Wraparound Violence Programs in California, could serve as a model to target at-risk populations and reduce recidivism.[16]

Furthermore, self-injury and suicide remain important public health issues, the rates of which continue to increase,[17] and more than half of which are firearm related.[18] In this study, intentional self-injury accounted for one-third of cases that resulted in significant injury. Several studies have shown that most of the firearm-related suicides occurred at the home of the victim and that having a firearm in the household was associated with an increased risk of firearm-related suicide.[7,19,20] Consistent with reports in the literature, our study shows that the mortality rate was highest in this group,[21,22] a finding that can be attributed to the fact that most injuries under this category were directed to the head and neck region. We also observed that alcohol use and a history of

Table 4
Multivariable regression model to determine independent risk factors, of being a victim of a fire-arm injury in the American household.

	Victim of assault	Victim of intentional self-injury	Victim of unintentional injury
Factors independently associated with injury (OR, 95%CI, P-value)	Age <45 years (2.0, 1.9–2.2, P < 0.001)	Age >65 years (3.0, 2.9–3.5, P < 0.001)	White Race[a] (2.5, 2.3–2.9, P < 0.001)
	African American Race[a] (9.3, 8.4–10.3, P < 0.001)	White Race[a] (4.9, 4.5–5.6, P < 0.001)	American Indian Race[a] (4.5, 2.8–7.3, P < 0.001)
	Hispanic Ethnicity (3.7, 3.2–4.2, P < 0.001)	Alcohol use disorder (1.5, 1.3–1.7, P < 0.001)	
	Drug use disorder (2.2, 1.9–2.5, P < 0.001)	Psychiatric illness (3.8, 3.3–4.3, P < 0.001)	

[a] Odds ratio comparator is not being a member of that race.

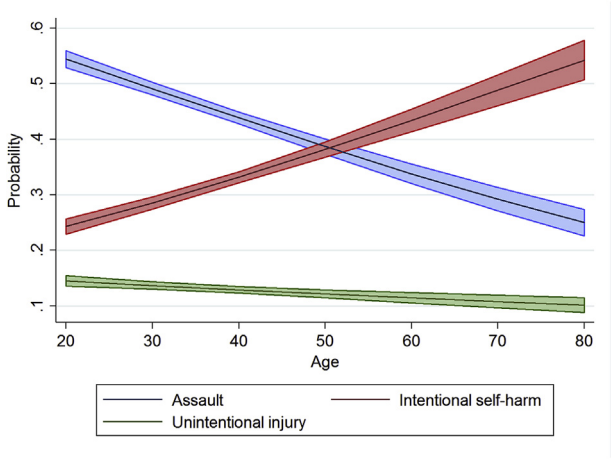

Fig. 3. Adjusted probabilities (with 95% confidence intervals) of being a victim of assault, intentional self-injury, and unintentional injury across age (years).

psychiatric illness are both independent predictors of attempted or completed suicide. This is further consistent with the literature, whereby it has been shown that suicide risk is increased in persons with mental illness, especially in the depressive spectrum.[23] Moreover, Branas et al. performed a systematic review and meta-analysis that revealed that alcohol plays an important role in firearm violence, especially among self-inflicted firearm injuries.[24] This finding is critical as federal law does not prohibit known alcohol abusers from obtaining a firearm, as it does ban known illicit drug users from purchasing weapons.[14,25,26]

Unintentional firearm discharge was a less frequent cause of injury than assault or self-inflected injuries. Previous studies have shown that unintentional injuries are regularly the consequence of inexperience in handling firearms, improper storage of a loaded weapon, and improper locking.[27,28] For this group, firearm education and preventing access by promoting safe storage may be the best strategy in injury prevention.[29] Interestingly, in this analysis, race was an independent predictor for this type of injury. Guetschow et al. has shown that hunting season was associated with an increased rate of unintentional firearm injury in rural areas, and perhaps the involvement of people of White race in the activity, who constitute the majority of our cohort, accounts for this finding.[27]

Household firearm-violence disproportionately affects men, but in unique aspects, depends on age and racial identity. Racial disparities in firearm-related injuries and death have been well established in the United States.[30–32] The National Vital Statistics System (NVSS) between 2010 and 2012 revealed that the annual firearm homicide rate for non-Hispanic African American individuals was about 10.3 times higher than the rate for non-Hispanic White individuals. In contrast, the annual rate of firearm suicide among whites was 2.9–3.7 times higher than the rate for African American individuals.[9] This study showcases that persons of different races suffer the burden of gun-violence differently. These nuances suggest that a one-size fits all policy will be ineffective in preventing gun-related injuries. We propose that specific prevention strategies that target these individual groups would be most effective, and envision partnerships between the community, health care systems, social services, local government and law enforcement agencies to coordinate policy and programs to identify at-risk individuals for potential misuse of firearms. These strategies should include enhanced background checks for gun ownership, and improved access to health care in order to adequately address psychiatric illness and substance abuse disorders.

This study has several limitations. First, this is a retrospective study and although encompasses prospectively collected data rich in clinical detail, there is a lack of granularity into the circumstances surrounding these events. For instance, it is possible that injuries due to assault may have been caused by a firearm not originating from the household. Moreover, numerous psychiatric diagnoses are aggregated in the ACS-TQIP 'psychiatric disease' variable which was found to be associated with self-inflicted injury. In medical reality, individual suicide risk will vary based on the specific psychiatric diagnosis. Second, deaths at the scene or in-transit, or patients with minor injuries were not captured in the database and thus a comprehensive evaluation of the burden of firearm inflicted injuries is not represented here. Finally, the independent associations identified in this study are correlations and do not imply cause-and-effect. Further research is needed to produce a more informative representation of gun violence and injury patterns in the U.S. to develop effective and individualized prevention strategies or policies.

Conclusion

Assault is the most common cause of home-related gun violence requiring admission to ACS-TQIP verified trauma centers, while intentional self-inflicted remains the most lethal.

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